SMITH

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View of Diamond Creek dam site, looking upstream.

THE COLORADO RIVER AND ARIZONA'S INTEREST IN ITS DEVELOPMENT

By G. E. P. Smith

Tucson, Arizona, February 25, 1922

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The Colorado River and Arizona's Interest in Its Development*

By G. E. P. Smith

It is nearly four hundred years since Spanish explorers discovered the canyons of the Colorado River. During these centuries mankind has coped with many problems and has surmounted great obstacles. But the six hundred mile stretch of canyon of the Colorado of the West is still under nature's control. No stone has been turned to impede the flow of water; no revolving wheel converts the power of the flood to useful purposes.

The development of the great river is a stupendous problem. Not alone is the layman staggered by the difficulties involved and by the immensity of the stakes, but the engineer is challenged and is struggling to conceive of the gigantic works that are required,—dams of twice the height of the highest dam yet attempted, reservoirs twelve to twenty times as large as the largest artificial reservoir in the world, and power generation on a prodigious scale.

GEOGRAPHY AND IRRIGABLE LANDS

Before presenting the problems of the Colorado River it may be helpful to review the geography of the region and to present a digest of the character and extent of the water supply.

The drainage basin of the Colorado is shown in Fig. 1. It includes parts of seven states,—the southwestern part of Wyoming, the western half of Colorado, the eastern half of Utah, a strip along the west side of New Mexico, all of Arizona except the southeast corner, the southeast part of Nevada, and the southeast edge of California,—in all, 251,000 square miles. The watershed on the east side of the basin is the Continental Divide, from the Mexican boundary line almost to Yellowstone Park. All of the northern half of the basin, and part of the southern half, consists of high, mountainous country, on which there is a heavy annual precipitation.

Until a year ago that part of the stream system draining western Colorado was called the Grand River. In the southeastern part of

*An address delivered at the Annual Farm and Home Week at Tucson, January 18, 1922. It was voted by the audience that the address should be published, and in response to the widespread demand for authentic information on the subject, the paper is included in the bulletin series. —Publication Committee.

Utah that stream unites with the Green River, the head waters of which are in Wyoming. Below the junction of the Grand and the Green the stream was called the Colorado. A year ago, by Congressional action, the name of the Grand was changed to Colorado; presumably geography and, ultimately, public usage will adopt the new name for the upper river. The principal tributaries below the junction of the Green and the Grand are the San Juan, flowing westerly from the northwest corner of New Mexico; the Little Colorado, which drains the north side of the Mogollon Rim in Arizona; and the Gila, which drains the central and southern parts of Arizona.

In the upper basin, that is, the basin above the Grand Canyon, there is a large area of land under cultivation, about 1,500,000 acres, mostly on the headwaters and tributaries where diversions from the streams are easily accomplished. The irrigation of the land, however, requires comparatively little water, on account of the high altitude, cold climate and short growing season, and part of the water applied returns underground to the streams. An even greater area, now idle, is susceptible of irrigation, part of it, however, at such high cost as to make the projects of doubtful feasibility. Studies made by the United States Reclamation Service indicate that the irrigated area in the upper basin will be increased to 3,000,000 acres.

In the lower basin, below the Grand Canyon, the areas irrigated in 1920 included 39,000 acres between Needles and Yuma, mostly on the California side; 54,000 acres in the Yuma project; 415,000 acres in the Imperial Valley; and 190,000 acres south of the international boundary line,—a total of 698,000 acres. This total is almost exactly double the acreage irrigated in 1913, showing the rapid rate of increase in the use of water in the lower basin. The possible extension of irrigation in the lower basin has not been determined fully, but conservative estimates indicate that the following additional areas can be brought under irrigation:—260,000 acres between Needles and Yuma, 150,000 acres of which is on the Arizona side; 76,000 acres in the Yuma project; 400,000 acres in the Imperial and Coachella valleys; and 630,000 acres in Mexico.

WATER SUPPLY

Engineers have methods, of comparative accuracy, for measuring the quantity of water flowing in rivers. The record of the flow, day

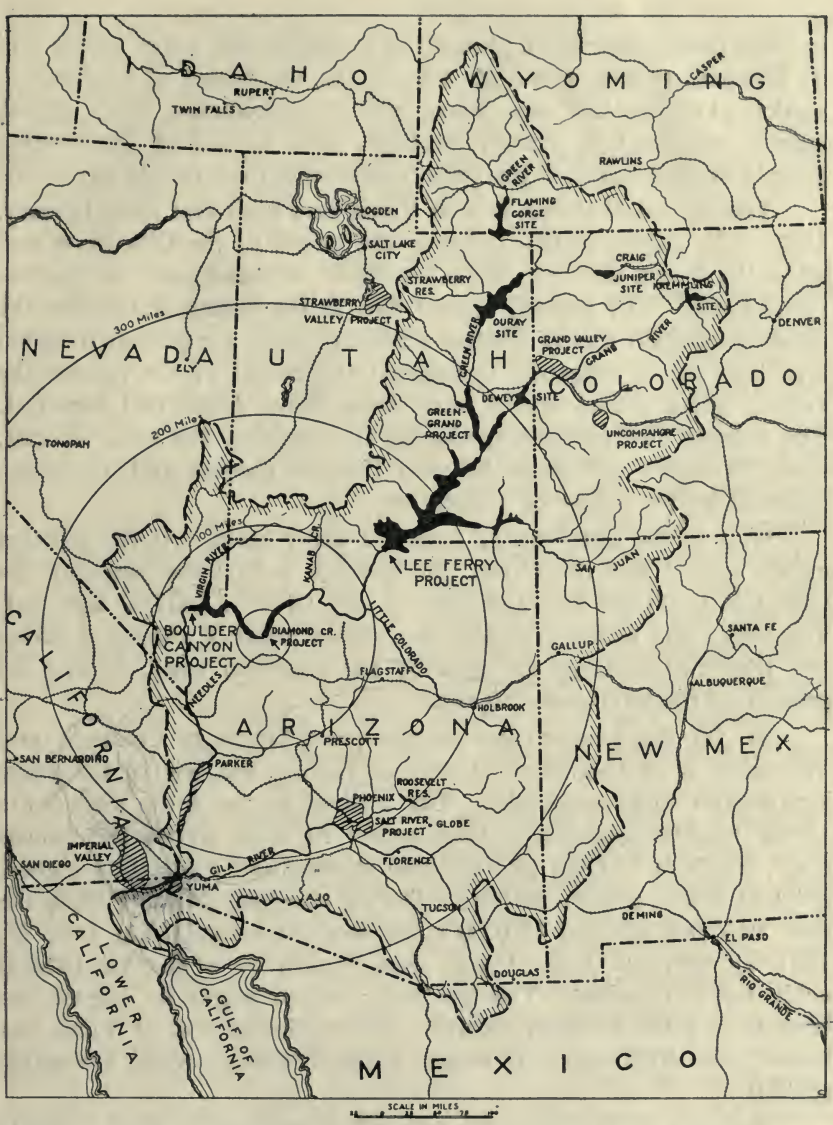

Fig. 1. Map of drainage basin and river system of the Colorado River. The drainage basin is shown by the shaded line.

by day, month by month, shows the extent of the water supply and its fluctuations, and furnishes a basis for the design of engineering works. On the Colorado River and its tributaries, many gaging stations, at carefully chosen locations, have been kept for varying periods of time, some of the records extending over twenty-five years.

The records of stream flow at Yuma have been kept since January, 1902. The gaging station is below the mouth of the Gila River and below the Yuma diversion dam, but above the head gates of the Imperial Canal. The average annual flow at the gaging station for the period 1902-1920 was 17,300,000 acre-feet. Had the present irrigated area been under irrigation throughout the period of the record, the average annual flow would have been about 16,000,000 acre-feet. The average flow at Boulder Canyon is practically the same amount, since diversions and losses between Boulder Canyon and Yuma are balanced by the inflow of tributaries.

Most of the water comes from the upper basin. At the junction of the Grand and the Green, the average annual discharge of the Grand is 6,900,000 acre-feet, and of the Green 5,500,000 acre-feet. The Green and Grand and San Juan rivers together, though draining less than two-fifths of the area of the Colorado basin, furnish 86 percent of the total water supply.

By far the greater part of the precipitation in Colorado and Wyoming is in the form of snow. During the winter the snow accumulates to great depths. The melting of the snow during the spring months produces a long period of high water, the annual flood, which lasts from two to three months and reaches its highest point at Yuma usually in June. During the June flood of 1909, the flow at Yuma reached 150,000 cubic feet per second. On June 27, 1921, all previous June records were broken by a flow of 186,000 cubic feet per second. The low water season begins in August and lasts from three to seven months. The minimum flow at Yuma has been below 4000 cubic feet per second during several low-water seasons.

The Gila River drains an area of 57,000 square miles. While the average annual discharge of the river is not great, it is very variable. In 1916 the discharge of the river at its mouth was 4,500,000 acre-feet; in some other years the total has been less than 100,-

000 acre-feet. Short-lived, "flashy" floods, greater than the highest peak floods in the Colorado, occur at times. The flow on January 16, 1916, reached 220,000 cubic feet per second. It is fortunate that the Gila floods do not come at the same time as the Colorado floods, in May or June. Should they coincide, the menace to the Yuma and Imperial valleys would be intensified; the levees would be overwhelmed.

RESERVOIR SITES

There are scores, hundreds, of storage sites in the middle and upper parts of the Colorado basin. Many of them have been surveyed, and at several of the sites the depth to bedrock has been ascertained by diamond drilling. The Strawberry Valley site in Utah and the Roosevelt site in Arizona and some small sites have been occupied already. For the complete regulation and utilization of the river, there are adequate natural opportunities; the real problem is as to which is the best. A few of the largest and most promising sites, those which are of greatest public interest, will be discussed.

The Dewey reservoir site is situated on the Grand River just west of the Utah-Colorado line. Although one of the last to be discovered, it is one of the best. It is the only site for a large reservoir on the Grand River except the Kremmling, and that site is occupied by a railroad. The bedrock at the Dewey site is only 44 feet below the river bed, and the capacity with a dam only 215 feet high from river bed to spillway is 2,300,000 acre-feet.

The Flaming Gorge site is on the Green River in Utah just south of the Wyoming line. The greatest depth to bedrock is 73 feet, and a 215-foot dam will impound 3,120,000 acre-feet. The width of the canyon is 200 feet. The Flaming Gorge and the Dewey sites control the most important headwaters of the Colorado. Both are excellent projects and should be under construction today.

Another excellent site is on the Yampa tributary, near Juniper Mountain. The drainage area is small, but the stream flow approximates 1,000,000 acre-feet of water per year. A 200-foot dam would provide a capacity of 1,500,000 acre-feet. The depth to bedrock is 24 feet.

The Ouray reservoir site is on the Green River a hundred miles below the Flaming Gorge site. This site is remarkable in that a dam

only 210 feet high would impound 16,000,000 acre-feet of water. The greatest depth to bedrock, a factor of great influence on the cost of a dam, is 121 feet, and the canyon is not narrow. This site should be held available by the Federal Government until it is absolutely certain that the site is not needed in the general scheme for development of the river. If the site is restored to entry, it will be seized at once by the Denver and Salt Lake Railroad. The railway can be built around the reservoir site.

A reservoir at the junction of the Green and the Grand has been under consideration for many years. It would regulate partially both streams. A dam 250 feet high would impound 7,450,000 acre-feet. Borings were made to 120 feet without encountering bedrock. It is unfortunate that the borings were not carried somewhat deeper.

An apparently excellent reservoir site exists on the San Juan near Bluff, Utah, but its feasibility has not been established by test holes to find bedrock. A dam 264 feet high would create a reservoir of 2,600,000 acre-feet capacity. The accumulation of silt in this reservoir would be very rapid.

The Glen Canyon, or Lee's Ferry, site outclasses all other proposed sites in its gigantic possibilities. The maximum development contemplates a dam 700 feet high, 450 feet long at the level of the river, and 1400 feet long on top. The proposed slopes are one to six downstream and one to four upstream, making the length of base up and down stream over a mile.. The capacity of the reservoir would be over 50,000,000 acre-feet, and 86 percent of the entire water supply of the Colorado basin would be regulated completely. Over a million continuous horsepower could be developed without sacrifice of irrigation interests. Complete surveys of the reservoir site have been made during the last few months. No test borings have been made, and it is stated that the depth to bedrock is not a crucial matter on account of the radical character of the dam contemplated. Test borings should be made at once.

Excellent dam sites exist in Cataract Canyon and Marble Canyon. The project for Marble Canyon provides for a power development of 1,300,000 horsepower, but the storage possibilities are small. This will be the last of the major projects because of its magnitude and high cost.

On the Little Colorado River, there is a dam site at Tolchaco, where the entire flood flow of that stream can be controlled by a dam 50 feet high.

The site at the mouth of Diamond Creek is of particular interest to Arizona, on account of its favorable location and because it is controlled by Arizona people. The site is only 16 miles from Peach Springs, a station on the Santa Fe Railroad. It is a power project only, there being practically no storage. Present plans, subject to modification, call for a dam 284 feet high, 324 feet above bedrock, to the spillway crest, and the top of the structure would be 25 feet higher. About 110,000 horsepower could be developed with the unregulated flow of the river, but in case the flow is equalized by a project with storage farther up the river, the ultimate power development may reach 600,000 horsepower. The canyon at this site is only 220 feet wide at the water level, and the length of the dam at the top will be 600 feet, about the same as the Roosevelt dam. The walls and foundation are of granite. The main electric transmission line would extend through, or near, Prescott, Phoenix, Mesa, Florence, and Tucson to Douglas, with important laterals to Jerome, Ray, Globe, Clifton, Ajo, and Yuma.

The Boulder Canyon site is in a similar narrow canyon in granite rock. The canyon walls are 300 feet apart. Here it is proposed to build a solid concrete masonry dam 600 feet high, 735 feet above bedrock, to elevation 1300 feet above sea level. The capacity of the reservoir is 31,600,000 acre-feet, and the estimated cost of the dam alone is $55,000,000. The great depth to bedrock is the main disadvantage of this site. While the problems of carrying the foundation to so great a depth and of passing the annual and occasional floods of the river during the construction period strike terror to the heart of the engineer, the task can be accomplished if adequate funds are provided. The power development will be 700,000 continuous horsepower as long as the irrigated area in the lower basin does not exceed 1,500,000 acres, and will decrease to 600,000 horsepower as the acreage increases to 2,000,000 acres.

The last annual report of the United States Reclamation Service states that an inspection of the lower river was made by boat by Homer Hamlin, a noted engineer, in April, 1920, and that he reports that

there is no good dam site for a storage reservoir between Boulder Canyon and Yuma.

THE THREE GREAT PROBLEMS

Three objects are sought in the development of the Colorado River. They are:—

1. Storage for flood protection;
2. Storage to provide more water for the latter half of the irrigation season and for dry years; and,
3. Hydro-electric power.

The flood protection is the main incentive which is spurring many agencies to action. The people of the Imperial Valley, for 16 years, have been fighting a defensive battle against the Colorado, sometimes gaining, sometimes losing, but in the main losing. They cannot hold out for many more years. At least once every year, in June, and sometimes at other seasons, the river threatens to change its course from the Gulf of California to the Imperial Valley, as it did in 1905. The only protection at present is the system of levees, called respectively the first, second, and third lines of defense. Frequently the floods break through the first and second lines and reach the third line. Each year the river, through silt deposition, builds up that part of the alluvial fan in front of the levees, in some years as much as four feet, and each year the levees must be raised an equal amount. Over one-quarter of a million dollars is expended each year by the farmers of the Imperial Valley in this work. The limit will be reached soon. Levees forty or fifty feet high cannot be maintained.

The Yuma Valley, also, is protected by levees, but the danger there does not increase. Arizona hopes to develop another great irrigated valley farther upstream at Parker, but much of the Parker Valley is now subject to overflow and must be protected by an expensive system of levees unless adequate regulation of the floodwaters is provided by storage reservoirs. Regulation of the Green and the Grand will solve the problem in large measure, but tributaries below the junction must be given consideration. On one occasion a flood of 150,000 second-feet measured at Bluff, Utah, was contributed by the San Juan, and the Gila River floods likewise are a menace with which to reckon.

As for storage to equalize the supply for irrigation, the situation is more critical than is commonly known. Despite the great excess of

water which is wasted to the ocean each year, there is an actual shortage during the latter part of the irrigation season in dry years. In 1915 the entire flow of the river was diverted into the Imperial Canal at the end of August, and yet there was not enough water to meet the demand. Since that time the acreage irrigated from the river has increased 300,000 acres. If the natural flow next September is as low as it was in 1915, there will be 300,000 acres of crops without any water to bring them to maturity, and the financial loss and human suffering will be appalling. Again, it is the Imperial Valley that is in danger, for other projects have the advantage of location upstream. No further expansion of irrigation use should be allowed until storage is provided; it should be admitted that the natural flow is entirely appropriated. It does not seem practicable, however, to prevent continued appropriation and use of water in Utah and Colorado.

But how can storage be financed? The Imperial Valley is burdened already with a heavy bonded indebtedness and is facing the further problem of the All-American Canal, which is expected to cost $30,000,000. The farmers cannot finance the river regulation which they require and must have.

Now enters the third element of the great project—power. The power possibilities are so great, and power is so valuable, that it is estimated the sale of power will pay for the entire project. A few months ago the proposal was to charge five percent of the cost of the storage dam to irrigation, ten percent to flood protection, and eighty-five percent to power. Now it is proposed to charge the entire cost to the power privileges. About 4,000,000 horsepower can be developed in Arizona at the four sites mentioned above.

Is there a market for so much power? Arizona can take about 100,000 horsepower to replace present steam plants. Cheap power will permit of increased pump irrigation, the mining of lower grade ores, and the electrification of our railways. We shall have factories where our own raw materials can be fabricated,—cotton mills, copper and brass foundries; and the electrolytic refining of Arizona copper can be done in our own State. All city and house lighting will be done with hydroelectric power, and any excess can be used for making nitrate fertilizers.

But other states, especially California, will compete for the power. A great amount can be marketed in southern California now. It is

estimated that in fifteen years all possible hydro-electric development in that State will have been accomplished, and California interests are looking much farther ahead than that.

Nearly all of the power requirements of the mining industry in Arizona are now supplied from petroleum fuel oil. The best opinions regarding the future supply of fuel oil point to a diminution of the supply and rapidly rising prices. It is essential that hydro-electric power be developed to replace the failing oil supply.

PROPOSAL OF THE UNITED STATES RECLAMATION SERVICE

Engineers of the United States Reclamation Service have been studying the problem of the Colorado for eight years, and have decided quite definitely on what they believe should be the first project. The Service has recommended to Congress that it should be a project of the Federal Government, and the Secretary of the Interior stated publicly at the Riverside and San Diego conventions in December, 1921, that, because of the international and interstate character of the river, the Federal Government is the only competent agency to construct the great dam that must be built, and to control and operate its gates. He is right, and Arizona should back to the limit federal ownership and operation of the main river control project.

The Reclamation Service recommends that the dam be located in Boulder Canyon on the boundary line between Arizona and Nevada. On account of the peculiar situation, the west end of the dam would rest on the Arizona side. A transmission line from that point to Phoenix would be about 250 miles long, and a line to Los Angeles 277 miles in length. The proposed 600-foot dam provides for storage for irrigation and for storage of silt for sixty years, and for 5,000,000 acre-feet capacity at the top to be used only for detention of high flood crests, such as those of 1907, 1909, 1914, and 1920.

Last July, when Congress was committed to retrenchment, and it seemed impossible to interest the East in this most necessary undertaking, plans were made to contract the power privileges in advance to municipalities and states or to other purchasers, and the purchasers were to obtain the necessary funds through sale of bond issues. The city of Los Angeles was ready to take all or as much of the power as would be allowed to that city. Now, it is believed that there is a good fighting chance to obtain the money through federal appropriation,

with ultimate return of the cost to the government by the sale of power.

ALTERNATIVE PROPOSALS

Although crystallization of sentiment in favor of Boulder Canyon project has made considerable headway, still some widely divergent views are being expressed, and it may not be impertinent to discuss alternative proposals. It is contended that for many reasons the river development should begin farther upstream. That the Boulder Canyon site is the one nearest to the best market for power is a sound argument. Of the other arguments advanced for that site, some are not valid, and the others may be met by the statement that extensive storage in the upper basin can be followed advantageously, and will be, by projects providing additional storage on the lower river. If the flood hazard is removed or is greatly reduced by means of extensive storage in Utah, the Boulder Canyon dam can be built at much less cost and in fewer years. Further, if the river regulation is effected in the upper basin, the power sites from Glen Canyon to Boulder Canyon inclusive become much more valuable, since the water supply is equalized, and because less reserve space is required for detention purposes. The upper locations will be developed eventually; why not now?

From that standpoint, the Dewey site on the Grand River and the Flaming Gorge site on the Green offer the best solution. Both dams could be built at once, and the total cost would be only about $25,000,000. The Juniper Mountain reservoir would cost $4,000,000. These sites are above the great silt-gathering area of the drainage basin. The Flaming Gorge and Dewey reservoirs would provide ample late-summer water supply for the lower basin for many years to come. The Flaming Gorge reservoir would serve to reduce the spring floods on the Green River one-third, and the Dewey reservoir would take the peak off from the spring floods of the Grand. The Dewey reservoir would be operated so as to be entirely empty at the beginning of the flood period. Both dams could be completed in five years. It is premised, however, that the construction of these dams would be followed by that of one or more others farther downstream,—possibly one on the San Juan or at Lee's Ferry, and either the Diamond Creek dam or Boulder Canyon dam or both. The dams on the headwaters should be built under the same theory of government as were the

thirty-three dams on the Ohio River, that is, to secure river regulation and control, to make the stream manageable and utilizable. Navigation is no more vital to the economic and social welfare of the group of six states bordering the Ohio than is the taming and harnessing of the Colorado to the welfare of the seven states along its course. In due time, the Government might be reimbursed for the investment, for, after the construction of large storage reservoirs in Arizona, the Utah reservoirs would be of great value for power production.

The Diamond Creek project is capable of comparatively rapid construction, and is quite likely to go ahead of the Boulder dam in point of time. It would be a strictly Arizona enterprise, and free from the entangling jurisdictions that are inevitable in the larger projects. It does not in any way lessen the necessity for the Boulder dam or some other dam which can provide storage and flood control.

Another proposal is to make the Lee's Ferry reservoir the first major undertaking. On account of the type of dam planned, the extent of flooding in the river during construction would be immaterial. This reservoir as planned would store 30 percent more water than the Boulder Canyon reservoir, the production of power would be much greater, and the cost would be less. However, on account of the radical design and proposed methods of construction, the project should be submitted to the best engineering talent in the world before it can be right or wise to adopt it.

WATER RIGHTS

The Supreme Court of the United States has decided that in the case of interstate streams in the arid region, neither the riparian theory of water rights nor the priority of appropriation theory can obtain, but that each State is entitled to benefits from the river,—to substantial benefits. Presumably, the distribution of benefits must be made by the federal court. But in the case of the Colorado River, where there is water enough for all, there seems to be no necessity for any litigation.

The states of the upper basin seem to fear that the construction of large reservoirs will serve automatically to appropriate the waters of the river for use in the lower basin, and that additional development of irrigation in the upper states will be prevented. Oft-repeated assertions of the United States Geological Survey and the United States

Reclamation Service that the water supply is ample and adequate for all of the irrigable lands of both upper and lower basins have not served to allay the fear. Another cause of alarm in Colorado is the doubt as to whether that State will be allowed to divert 310,000 acre-feet of water per year from the Colorado basin, through tunnels at narrow places in the watershed, for use on the plains north and east of Denver, as is desired.

The upper states therefore are demanding a guarantee of unrestricted irrigation development in the upper basin, before they will lend their support, or consent, to a federal project in the canyon region. The lower basin states are asking for an allotment of the water supply among the seven states.

The wisdom of a perpetual guarantee or of an allotment of the waters of the river is questionable. On no other river basin has either been attempted. It is not possible to forsee conditions a hundred years ahead, or even thirty years ahead. All irrigators who are putting the water to beneficial use should be protected, but in principle it may be exceedingly dangerous to reserve a valuable water supply for a project which may prove to be of doubtful feasibility. If an allotment of the water is attempted, most of the seven states will advance extravagant claims to water. Some of the states most involved have no adequate conception of the feasibility of their projects, and no just allotment can be made without thorough surveys of all proposed irrigation lands. It is unlikely that any allotment can be proposed which will not be held up in some legislature for many years, and meanwhile the ruin of the Imperial Valley may be accomplished.

There is no necessity for a distribution of the unused water rights at this time. If the act to appropriate money for a Colorado River project shall state as follows, "Provided, that nothing in this Act shall be so construed as to affect in any way the rights to the use of the waters of the Colorado Basin of any state or any part of a state," then the upper states cannot be affected adversely by the project.

The average annual discharge of the river into the Gulf of California is 13,000,000 acre-feet. The projects of the upper basin are such that probably no more than 3,000,000 acre-feet of water additional can be consumed in those projects, and the balance of 10,000,000

acre-feet is more than twice as much as the states of the lower basin can use,— at least until a different economic order shall prevail.

Congress, through the Mondell act, has provided for a Colorado River Commission, consisting of one representative from each of the seven states, and one from the Federal Government. The Commission is now organized with Herbert Hoover as its chairman, representing the Federal Government. The purpose expressed in the Mondell Act is the negotiation of a compact or agreement, providing for an equitable division or apportionment of the water supply among the seven states.

NAVIGABILITY

The existing treaty with Mexico declares the Colorado River to be a navigable stream, and a federal court prohibited any action which might interfere with its navigability. The diversion of water for irrigation, therefore, is contrary to the treaty. As soon as diplomatic relations with Mexico are re-established, steps should be taken to amend the treaty in so far as it affects the Colorado. The river should be declared to be an unnavigable stream.

ARIZONA'S PROGRAM

Arizona owns the Colorado River bed, or half of it, for 580 miles. We do not own the water. We do not have unlimited millions of wealth to invest in the Colorado enterprises, nor many votes in Congress. We should endeavor to cooperate with our neighbor states. When the seven states agree upon a plan of action, the extreme urgency of the case will secure the appropriation needed.

With regard to some features of the project, Arizonans will express their opinions, but should not insist upon them. The immediate construction of the storage dam and the height of dam and the type of dam are far more vital to California than to us. Nothing can prevent our obtaining all the power the State can use, both now, and for fifty years to come. Our preferential rights to power are recognized. Also, it is proposed to grant Arizona and Nevada each a free block of power at Boulder site. Our concern must be to insure that there shall be no monopoly of power by a single corporation, and that every nook and corner of the State shall be able to receive power at equitable rates.

We should pledge the State's honor to the states of the upper

basin that any construction of dams for the benefit of the lower basin shall not prejudice in any way their equitable rights.

But, the irrigation of our lands we must insist on; the development of the Parker project of 110,000 acres and of the Mohave Valley of 27,000 acres, and of the Cibola Valley of 15,000 acres, and that the right to double the acreage under irrigation at Yuma, as is contemplated, shall not be denied. It will require at least two new diversion dams similar to the Laguna dam, and they must be started in time to be finished when the storage dam is finished. The great river control dam and the power will be secured largely because California is fighting with us. But for the irrigation of Arizona lands we must fight alone. It does not follow necessarily that our lands will be irrigated if the Boulder dam or Lee's Ferry dam is built. Provision for the Parker diversion dam should, if possible, be put into the act which shall provide for the larger project. Be it said also, that the Parker and Mohave projects do not have the usual influential citizens and real estate boosters to present their claims. They are still under the care of the United States Indian Service. Congress passed an act for their opening to entry several years ago, and the matter is now sleeping. There are only a few Indians, and they have received allotments. It is the finest opportunity in the whole United States to provide lands for former service men, not less than 3500 of them. The State of Arizona has got to speak loudly for those projects.

Lastly, the high-line irrigation project — what of it? It has been claimed that if the high dam is located in Boulder Canyon, water can be turned into a canal on a high level, and led through the mountain passes of Mohave County, across Bill Williams River, through the Bouse Valley to Harrisburg Valley, and down the Centennial Wash to the Gila River. The writer has studied all the available data, and is of the opinion that the project is not feasible. Regardless of how desirable it would be to bring under irrigation from the Colorado River an extensive area of elevated desert land, yet it is better for the people of Arizona to dream no vague dreams, and to concentrate all efforts to obtain those developments which are practicable.

In the first place, the high-line project would require a dam 500 or 600 feet high to raise the water to the level of the canal. A great reservoir of dead storage water would be created, for the water level could never again be allowed to fall below the elevation of the canal.

Storage to regulate and equalize the water supply must be provided by building the dam considerably higher than the canal level or by means of another reservoir, preferably at Lee's Ferry. Probably there would be two great dams required instead of one.

The high-line canal would be built along the rough mountain sides of Mohave County, but no water could be taken through the Sacramento Valley Pass or through any other pass to lands behind the mountain range that borders the river, in that county.

Assuming an elevation of 1200 feet above sea level for the canal at its head, the elevation in the vicinity of Bouse would be about 1050 feet, 120 feet lower than the proposed canal that is designed to irrigate the Bouse Valley from the Williams River. About 90,000 acres in the Bouse Valley could be irrigated by pumping from the canal. By boosting the water 350 feet by means of pumps, the water could be led to Vicksburg, and then another boost of 500 feet would deliver it into the Harrisburg Valley, or, perhaps it would be cheaper to avoid the last-named lift by tunneling through the Little Harquahala Mountains. It would be more feasible to leave the Little Harquahalas and Coyote Mountain to the east of the canal, but even so, the pumping lift would be impractical. The maximum area that could be brought under such a high line system would be less than a million acres, mostly in Yuma County.

As an alternative proposal, the water for the high-line canal might be dropped at the high dam, generating power, and this power could be used to lift the water from the river near Parker into a high-line canal starting at that point. The electrical transmission losses would be no larger in percentage than the seepage and evaporation losses of water from the 260 miles of canal; and the investment would be less. About one kilowatt would be required per acre irrigated for the main lift to elevation 1060 at Parker, requiring an investment of about $100 per acre for power equipment, while the cost of the canal from the high dam to Parker would be more than twice as much. The value of the power used on this one lift, per irrigated acre, at one-half cent per kilowatt-hour, would be about $30 per year. Neither proposition is feasible, at least not during the present generation. An investment of over $300 per acre would be required. The best raw valley land in Arizona cannot stand a construction charge

for irrigation over $150 per acre.

There is one possibility for which plans and estimates should perhaps be prepared. This is the possibility of pumping from the river at or near Cocopah Point, near the head of Laguna Lake, on a lift of about 350 feet, to a canal which would then run easterly on the north side of the Lower Gila Valley, crossing the river near Sentinel, and running thence on grade toward the southwest, covering about 250,000 acres of land. Power could be generated at Cocopah Point by means of a low rock-fill dam, after river regulation has been secured farther upstream. This project may be practicable twenty years hence.

THE GILA RIVER SYSTEM

It seems to have been forgotten that the Gila tributary is a vital element of the Colorado River, and that the study of Colorado River problems must take cognizance of the necessity for river regulation on the Gila. Be it remembered that it was the Gila River floods, five of them, in the winter and spring of 1905, which were responsible for the great disaster of that year, when in August the whole of the river was diverted into Imperial Valley. Had it not been for the continuous high water and repeated floods in the Gila, the narrow cut from the temporary heading of the Imperial Canal could have been closed easily. The Gila flood of January 22, 1916, was greater than the highest recorded flood of the Colorado itself. River regulation of the Gila River is absolutely necessary for the security of Yuma and Imperial valleys.

About seven years ago when the Federal Government began a comprehensive study of Colorado River problems, the Gila River was included in the studies. The plans prepared by the United States Reclamation Service at that time provided for regulation of the Gila by means of a dam 225 feet high near Sentinel, Arizona. The reservoir was to be operated for stream regulation only, and would have been of little service in reclaiming desert lands between Sentinel and Yuma. In 1918 borings were made at the dam site by the Reclamation Service, and it was ascertained that suitable foundations for a storage dam do not exist; hence the Sentinel project was abandoned.

In 1920, the Reclamation Service made an extensive study of the Gila River from source to mouth, examining all possible storage sites. It was concluded that the best solution of water problems of the Gila River is the construction of the San Carlos dam. The report of the

Engineer, Mr. C. C. Fisher, favors a dam 250 feet high above bedrock, about 20 feet lower than the Roosevelt dam. Mr. Fisher finds that the irrigation project should have an area of 148,000 acres. In February, 1921, a board of engineers of the United States Reclamation Service reviewed the Fisher report. The board recommends that the dam to be first constructed be 200 feet in height, and that in the next generation, thirty years hence, the height be raised to 250 feet. The board states that such a project is entirely feasible, provided satisfactory arrangements can be made with the Arizona Eastern Railroad, the line of which passes through the reservoir site.

The San Carlos dam must be constructed. Furthermore, storage must be provided on the Verde River. Additional storage is needed on the Salt River, and with this additional storage will come 24,000 additional hydro-electric horsepower at the Horse Mesa dam. It is hoped, too, that a feasible storage project on the Agua Fria can be accomplished, and perhaps the Walnut Grove dam will be rebuilt at some time. Each one of these projects will reduce materially the flood crests of the lower Gila River.

FINAL

Arizona's program, therefore, should be:—

1. To encourage all development projects, both public and private, on the Colorado River. In the case of publicly owned projects, the State must receive a block of free power in lieu of taxes.

2. To demand that as much power be allotted to this State as can be used by this State.

3. To demand that the federal project include a diversion dam at Bull's Head Rock at the head of Mohave Valley and one at Gatehead Rock at the head of the Parker Valley.

4. To demand that provision for river regulation on the Gila River be included in the federal program.

In the above exposition of the Colorado River problems and proposals, I have presented the case from the Arizona viewpoint. Arizona's future is to a high degree wrapped up in the development of the Colorado. The highest statesmanship is demanded at this time that the latent wealth of this great natural resource may be wisely and speedily secured and that this Commonwealth may share in its benefits in the largest practicable measure.